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PRODUCTION OF QUARTZ LIGHT GUIDES WITH AN ELLIPTICAL CROSS-SECTION USING CO_2 LASER

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Two principles of producing quartz light guides with an elliptical section using the radiation of CO_2 laser are described. The possibility of deformation of quartz preforms in the course of drawing quartz light guides is demonstrated. The process of manufacture of two types of elliptical quartz light guides is analyzed.

In addition to traditional applications of quartz light guides in communication technologies, a new extensive application area for them has recently emerged, i.e., measuring diverse external effects with sensors having a quartz light guide as a sensitive element. Single-mode quartz light guides are the most common ones. Single-mode quartz light guides preserving polarization of propagating radiation constitute a separate application area [1 – 3].

To propagate an electromagnetic field along a light guide preserving the state of polarization, a light guide with anisotropic properties across its section is needed. This can be achieved either by creating an elliptical core or by developing anisotropic radial stresses in the light guide section.

Contemporary technologies use several methods for producing anisotropic light guides. These methods are related to modifying the geometry of a quartz preform [2] and its subsequent constricting into a light guide with an elliptic core. One of the methods implies the insertion of additional glass rods into the preform, the coefficient of thermal expansion (CTE) of the rod differing from the CTE of the preform core [1]. In drawing such preform, anisotropic radial stresses are formed in the light guide. The above methods mechanically change the preform shape or mechanically replace its quartz part with a material slightly different from the core material. Note that this is a separate stage in light guide production. A disadvantage of these methods is the fact that the process is not controlled at the final stage, when an elliptical quartz light guide is being drawn. The preform in the course of deformation becomes contaminated by the deforming graphite heaters and these impurities later affect the strength and optical properties of the light guide. Radiation of a CO_2 laser makes it possible to produce both preforms for elliptical quartz light guides and light guides produced in a single technological cycle.

To implement this method for producing elliptical light guides, it is proposed to use multifunctional laser heating of the preform in the course of drawing light guides [4]. In this process anisotropy in the light guide is developed by its drawing from a standard single-mode quartz preform heated by laser radiation with a gradient of the distribution of this radiation power density on the preform. Such heating produces two types of elliptical quartz light guides. The first type is a light guide with an elliptical section and an elliptical edge, and the second type has a circular section with an elliptical core. Both types of light guides traversing light radiation corresponding to the elliptic axes of the particular light guide preserve two orthogonal polarization states. The methods for producing such light guides differ in their distribution of laser radiation in the heating zone of the single-mode quartz preform.

To produce an elliptical light guide of the first type, a special heating regime is needed, in which a certain viscosity distribution across the section is developed in the preform – light guide constriction zone (in the bulb), which transforms the initial circular section of the preform into an elliptical section in the light guide. This can be accomplished by heating the bulb with four laser beams incident in the same plane and having pairwise different power. The power of the counter beams is equal. However, an experiment demonstrated that this method does not produce a great degree of ellipticity. Therefore, the preform was heated by two counter beams according to the scheme shown in Fig. 1*a*. The bulb surface zones located in the plane perpendicular to the axis of the beams were not heated by laser radiation. In this case a circular quartz preform can be constricted into a light guide with an elliptical section with the axes ratio $a/b = 2$.

A quartz light guide with an elliptical section was produced using the method described. The specified axes ratio

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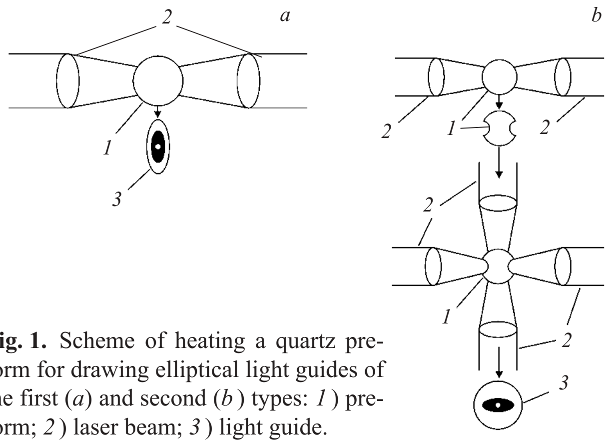

Fig. 1. Scheme of heating a quartz preform for drawing elliptical light guides of the first (*a*) and second (*b*) types: *1*) preform; *2*) laser beam; *3*) light guide.

appears to be maximum for this heating method, which is due to the following specifics of the method described. To create a sufficient viscosity gradient in the bulb section, the cross-section size of the laser beam incident on the preform should be decreased in relation to the preform diameter and at the same time its full power should be preserved. It is evident that the degree of decreasing the cross-lateral beam size with respect to the final diameter of the quartz preform drawn is limited by insufficient heating of the preform part, on which the laser beam does not fall. However, after reaching a certain size of the laser beam, which is not yet the ultimate size, the drawing regime becomes unstable and the position of the light guide periodically changes, shifting from one edge of the preform via its axis to its other edge.

The elliptical light guide of the second type is produced using a more complicated method (Fig. 1*b*). To do this, two grooves are evaporated in quartz glass on the preform (along its axis). Next, the quartz preform in the bulb zone is heated by four radially located radiation sources. In doing so, the preform under the effects of surface tension forces is transformed into a circular light guide with an elliptical core. In this method the process of evaporation of quartz glass layers and drawing a light guide are simultaneous due to spatial separation of laser beams. As a result, two beams keep evaporating the grooves and, as the preform keeps moving, the treated part gets into the heating zone, where a bulb is formed. By modifying the depth of the evaporating layer it is possible to control the degree of ellipticity of the quartz light guide drawn. We produced elliptical light guides according to the latter method.

The methods described have several differences. The first method is relatively simple to implement. However, the degree of ellipticity it produces is limited.

The second method technically is more complicated. It has two steps in the drawing line, since two processes are performed: evaporation of grooves and heating to draw a light guide. However, this method allows for higher degrees of ellipticity (a/b), since in this case it depends only on the size of layers evaporated.

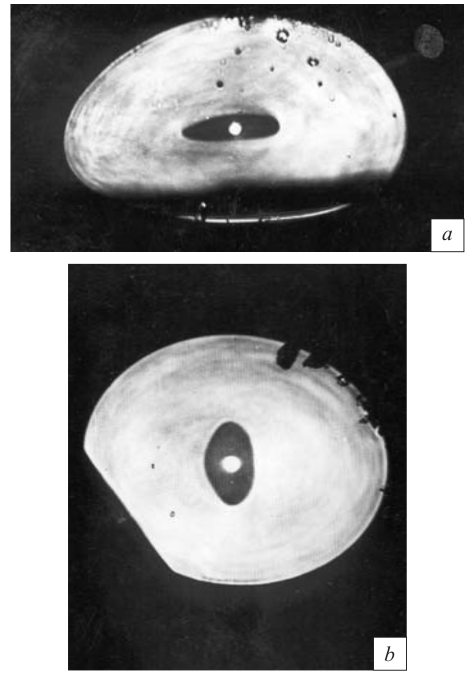

Fig. 2. Chips of elliptical guides of the first (*a*) and second (*b*) type.

The choice of a particular method should be made considering the required value of birefringence in the light guide that is to be drawn (Fig. 2).

In either method one can control the degree of ellipticity in drawing by varying the density of the laser beams. Both methods have an important advantage over the existing ones, namely, sterility of the process. A preform is treated by contact-free methods, and the processes coincide in time with drawing. All this makes it possible to draw quartz light guides having high strength [4].

There are several variants in production of preforms for drawing elliptical quartz light guides depending on the groove evaporation method.

The first variant is groove evaporation by a continuous CO_2 laser. This can be implemented by means of layer-by-layer removal of quartz glass; the groove in this variant becomes polished. However, with a large groove size and a moderate power of the continuous CO_2 laser (50 – 100 W) this may take a long time.

The second variant is evaporation of grooves using a pulse TEA CO_2 laser (of power 100 W) [5, 6], which makes it possible to obtain grooves with a more controlled shape.

A groove in a preform produced by a continuous laser has fused edges, whereas using a TEA CO_2 laser one has a more diverse selection of groove shapes, which can more uniquely determine the relationship between the shape of the elliptic core in the quartz light guide and the shape of the groove in the preform.

Essential advantages of both variants of laser deformation of preforms is the absence of contaminating components (abrasives, acids, etc.) and the possibility of automatic production of quartz preforms with a preset shape of the groove.

REFERENCES

1. Yu. N. Kul'chin, *Distributed Fiber-optic Measuring Systems* [in Russian], Fizmatlit, Moscow (2001).
2. R. Stolen, W. Pleibel, and J. R. Simpson, "High birefringence optical fibers by preform deformation," *J. Lightwave Technol.*, **LT-2**(5), 639 – 641 (1984).
3. S. C. Reashleigh and H. J. Marrone, "Polarization holding in elliptical core birefringent fibers," *IEEE J. Quantum Electronics*, **QE-18**(10), 1515 – 1523 (1982).
4. E. M. Dianov, V. N. Ionov, V. V. Kashin, et al., "Laser treatment of preform surface in drawing quartz light guides," *Pis'ma Zh. Tekh. Fiz.*, **11**(6), 473 – 476 (1985).
5. V. S. Aleinikov, Yu. D. Bondarenko, V. N. Volkov, et al., "Pulse laser based on carbon dioxide with lateral discharge without a system of work shift renewal," *Kvant. Elektronika*, No. 2, 381 – 383 (1981).
6. Yu. A. Baloshin, S. N. Gavrilov, I. V. Pavlishin, and A. O. Sen'kin, "A study of the possibility of using a pulse TEA CO_2 laser for treatment of brittle dielectric materials," *Optich. Zh.*, No. 8, 28 – 30 (1995).